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Faculty of Dental Medicine

INFLUENCE OF CONNECTION TYPE (INTERNAL VS. EXTERNAL) ON IMPLANT IMPRESSION ACCURACY: AN *IN VITRO* STUDY

Rita de Cássia Cabral Ventura

Master Degree in Dental Medicine

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Dissertation supervised by
Dr. Helena Francisco
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In memory of my Grandparents,

who never had the opportunity to see what I’ve become:

I hope you feel proud.

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Because no thesis is the work of just its author, i would like to express my gratitute...

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*To **Gonçalo**, who makes it all worthwhile. This is not my work, this is our work.*

Abbreviates

PMMA	Polymethyl Methacrylate
PE	Polyether
PVS	Polyvynil Siloxane
IC	Internal Connection
EC	External Connection

Abstract

Purpose: The aim of the present study was to evaluate if there was any significant difference in accuracy between implant-level impressions made on internal connection and external connection implant systems. The null hypothesis tested was that the accuracy of implant-impressions was not affected when internal connection or external connection implants were used.

Materials and Methods: Two master models were fabricated with polyurethane by duplicating an edentulous mandibular arch. In each model four implant analogs (Biomet 3i®, Florida, USA) – internal connection (Group A) and external connection (Group B) - were placed in the intra-mental foramen region, simulating a supra osseous clinical environment and with longitudinal axis parallel to each other. The replicas were numbered anti-clockwise from 1 to 4 based on a frontal view of the master cast.

For each group, reference bars machined to fit passively were fabricated using cobalt-chromium alloy. Twenty medium-consistency polyether (Impregum™ Penta™; 3M ESPE, Germany) impressions - 10 for each group - were made using the open-tray technique. Each cast produced was assessed for accuracy by attaching the respective reference framework with a single screw on analog number 1 and measuring the vertical gap between each cylinder and the respective analog (2, 3 or 4) at four different points - buccal, lingual, distal and mesial – using a toolmakers' microscope.

Results: The results showed there were significant differences between internal and external connections, comparing measurements in all analog/point combinations. It was determined that in Group B (External connection) the vertical gaps were statistically higher than the ones verified in Group A (Internal connection).

Conclusions: The results of this study suggest that internal connection implants present better results on the accuracy of implant impressions comparing to external connection implants. Implant-level impressions made on external connection implants resulted in statistically lower accuracy than the internal connection group.

Keywords: Implant connection, Internal connection, External connection, Impression accuracy.

Resumo

A reabilitação com implantes dentários de pacientes parcial e completamente edêntulos tem demonstrado elevadas taxas de sucesso clínico, consistentemente suportadas pela literatura. A otimização deste sucesso está diretamente relacionada com a passividade da infra-estrutura protética quando aparafusada a múltiplos implantes.

A passividade absoluta de uma prótese total fixa sobre implantes não é alcançável, como resultado das inúmeras variáveis envolvidas no processo de fabricação da mesma. No entanto, parece existir um certo nível de tolerância, sendo ainda desconhecido o grau de desadaptação da prótese face aos implantes que conduzirá a complicações biológicas e/ou mecânicas.

Um dos passos mais críticos para o sucesso a longo prazo de próteses implanto--suportadas é a precisão das impressões obtidas, que pode ser afetada por diversos fatores, tais como a técnica de impressão (moldeira aberta vs. moldeira fechada; ferulizar vs não ferulizar), o material de impressão, o tipo de impressão (convencional vs. digital) e a angulação e número de implantes.

Até à data, a influência do tipo de conexão do implante (interna vs. externa) na precisão de impressões em implantes permanece desconhecida. A informação existente na literatura sobre o desempenho deste fator, tanto *in vitro* como in *vivo*, é nula.

Objetivo: O objetivo do presente estudo laboratorial foi avaliar a possível existência de diferenças significativas entre a precisão de impressões à cabeça do implante obtidas sobre implantes de conexão interna e de conexão externa.

A hipótese nula testada foi: a precisão de impressões sobre implantes não é influenciada pelo sistema de conexão utilizado, seja ele interno ou externo.

Materiais e métodos: Foi obtido um modelo preliminar de gesso através da duplicação de uma arcada mandibular edêntula. Quatro buracos foram feitos bilateralmente, na região entre os foramens mentonianos, para a inserção de quatro réplicas de conexão interna (Biomet 3i®, Florida, USA) com 4,10mm de diâmetro. As réplicas foram colocadas simulando uma condição clínica supra-óssea, com eixos de inserção paralelos entre si e fixadas com cera para permitir a sua remoção após fabricação da barra de referência.

Sobre as réplicas, foram colocados cilindros de fundição correspondentes e unidos com cera, para posteriormente ser fundida uma barra de referência em crómio cobalto para o grupo de conexão interna (Grupo A).

Por forma a garantir a mesma posição das réplicas em ambos os grupos, foi fabricada uma barra de transferência: sobre as réplicas de conexão interna foram colocados multi-units de 1mm para conexão interna e as respetivas coifas de impressão (Biomet 3i®, Florida, USA) que foram ferulizadas usando resina acrílica autopolimerizável (GC pattern™; GC Corp, Tokyo, Japan). De seguida, todo o complexo foi removido do modelo e os componentes de conexão interna (multi-units e réplicas) foram substituídos por componentes de conexão externa. Deste modo, as réplicas de conexão externa foram inseridas no modelo inicial aparafusadas à barra de transferência.

Posteriormente, foi fundida uma barra de referência para o grupo de conexão externa (Grupo B), seguindo o mesmo protocolo usado para o Grupo A. As barras de referência fabricadas para os dois grupos foram utilizadas como forma de avaliar a precisão dos modelos obtidos através das impressões.

Com o objetivo de garantir uma completa passividade, as réplicas foram aparafusadas às respetivas barras de referência e, desta forma, reinseridas nos buracos do modelo preliminar. Para produzir os modelos finais, foram feitas matrizes de silicone de condensação (Zetalabor; Zhermack®, Badia Polesina, Italy) sobre o modelo de gesso com a respetiva barra aparafusada e corridas a poliuretano (Sherapolan 2:1; Shera®, Lemförde, Germany).

Obtiveram-se, assim, dois modelos (Grupo A e B) onde, em cada um, as réplicas foram numeradas de 1 a 4 no sentido anti-horário, baseado numa vista frontal do modelo.

Para o procedimento de impressão, foram utilizadas moldeiras standard, devidamente perfuradas para a técnica de moldeira aberta, sobre as quais foi aplicado adesivo para poliéter (Impregum™; 3M ESPE).

Foi realizado um total de 20 impressões – 10 para cada grupo – utilizando poliéter de consistência média (Impregum™ Penta™; 3M ESPE, Seefeld, Germany), de acordo com as instruções do fabricante. A mistura do material de impressão foi feita através de um sistema de automistura (Pentamix™ II; 3M ESPE, Seefeld, Germany) e parte do material foi meticulosamente injetado em volta das coifas de impressão para garantir a sua completa cobertura. A moldeira foi posicionada e mantida sob pressão manual durante 6 minutos. Em todas as impressões, foram utilizadas coifas de impressão (Biomet 3i®, Florida, USA) para a técnica de moldeira aberta.

As impressões foram corridas a gesso tipo IV (GC Fujirock EP®; GC Corp, Tokyo, Japan) misturado a vácuo e segundo as instruções do fabricante. Os modelos obtidos foram mantidos a temperatura ambiente durante um período mínimo de 24 horas antes da realização das medições.

A avaliação da precisão de cada modelo foi feita aparafusando a respetiva barra de referência apenas na réplica número 1 e medindo a discrepância vertical através do uso de um microscópio comparador (Toolmakers Microscope, Mitutoyo). As medições foram efetuadas entre a base de cada cilindro da barra de referência e a respetiva réplica (2, 3 ou 4), em quatro pontos diferentes – vestibular, lingual, mesial e distal.

A análise estatística de resultados foi realizada através do teste paramétrico T-student quando se verificou que a amostra seguia uma distribuição normal. Por outro lado, foi aplicado o teste não paramétrico Mann-Whitney quando esta condição não se verificou (Os testes de Kolmogorov-Smirnov e Shapiro-Wilk foram usados para avaliar se os resultados seguiam uma distribuição normal; o teste de Levene foi usado para determinar a igualdade de variâncias). O nível de significância estabelecido foi de 5%.

Resultados: Os resultados demonstraram existir diferenças significativas entre os grupos ao comparar as medições efetuadas para cada associação ponto/réplica específica.

A análise estatística determinou que no Grupo B (conexão externa) as discrepâncias verticais observadas apresentaram valores estatisticamente superiores ao Grupo A (conexão interna).

Conclusões: Tendo em conta as limitações deste estudo laboratorial, os resultados sugerem que implantes de conexão interna apresentam melhores resultados na precisão de impressões quando comparados com implantes de conexão externa.

Estudos futuros poderão proceder à avaliação e comparação de diferentes sistemas de conexão de implantes, no que diz respeito à sua influência na precisão de impressões. Além disso, seria importante avaliar *in vivo* se os valores de discrepância vertical obtidos neste estudo são clinicamente significativos.

Palavras-chave: Conexão do Implante, Conexão Interna, Conexão Externa, Precisão da impressão.

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I. Introduction

The rehabilitation of partially and completely edentulous patients with dental implants presents clinical success consistently supported by the literature. Longitudinal studies report an implant success rate of 96-99% in the mandible and 80-90% in the maxilla, for a period up to 15 years. Optimization of this success is directly related to the fabrication of passively fitting implant superstructures (Aguilar et al., 2010, Akalin et al., 2013).

According to the recommended standard of practice, clinicians' aim is to provide fixed implant prostheses that exhibit passive fit when connected to multiple abutments. The contact of all fitting surfaces is thought to minimize the uncontrolled stresses and strains within the implant components, the prosthesis and surrounding bone in the absence of an applied external load (Abduo and Judge, 2014, Buzayan and Yunus, 2014). Furthermore, because of the precise fit of implant components and the rigid connection of implant to bone, small discrepancies can lead to stress applied to the implants when the framework is screwed down (Del'Acqua et al., 2010a).

Several investigators have described the effect of accurately fitted complete-arch fixed implant prosthesis on long-term success (Papaspyridakos et al., 2011).

Although absolute passive fit of implant fixed complete dental prostheses does not seem attainable as a result of the number of variables involved in the process, a level of biological tolerance seems to exist. However, it is still unclear which at degree of prosthesis misfit will lead to biologic and/or mechanical complications (Papaspyridakos et al., 2014). Biologically, marginal discrepancy from misfit may cause unfavorable soft and/or hard tissue reactions like periimplant bone loss due to increase plaque accumulation. On the other hand, mechanical complications such as screw loosening, screw fracture, implant fracture and prosthetic-component strain and fracture are expected to emerge from compromised fit of implant prosthesis (Abduo and Judge, 2014, Lee et al., 2008b). In this context, an accurate three-dimensional reproduction of the intraoral position of the implants through the impression phase is necessary.

The clinical fit of an implant prosthesis at the implant-abutment junction is directly dependent on the accuracy of impression technique and cast fabrication (Papaspyridakos et al., 2014). Accurate implant impressions play a significant role and serve as a starting point in the process of producing good working casts, along with other contributing factors, such as pouring material/technique and machining tolerance of the prosthodontic components (Baig, 2014). Clinically, additional factors, such as number, angulation, and depth of implants may affect the accuracy of implant impressions (Papaspyridakos et al., 2011).

One of the most critical steps for the long-term success of implant prosthesis is the accuracy during the impression procedure, which may be affected by factors such as impression technique (open-tray vs. closed-tray; splinting vs. nonsplinting), impression material, impression type (conventional vs. digital) and implant angulation and number (Baig, 2014, Moreira et al., 2015).

Numerous studies have focused on the accuracy of multiple-implant impressions in completely edentulous arches, but no specific guidelines have been laid out pertaining to impression making in this particular situation (Papaspyridakos et al., 2014).

1. Factors may influence the accuracy of implant impressions

1.1. Impression technique (Open-tray vs. Closed-tray)

An ideal impression technique would require minimal time and would be easy to perform, inexpensive, comfortable for the patient and, of course, give the best results (Del'Acqua et al., 2010a).

Several impression techniques have been proposed to provide a definitive cast that will ensure accurate fit of the prostheses on osseointegrated implants. There are two primary techniques: The transfer technique and the pick-up technique. The transfer technique uses tapered copings and a closed tray to make an impression. The copings are connected to the implants, and an impression is made and separated from the mouth, leaving the copings intraorally. The copings are removed and connected to the implant analogs, and then the coping-analog assemblies are reinserted in the impression before fabricating the definitive cast. The pick-up technique uses square copings and an open tray, allowing the coronal end of the impression coping screw to be exposed. Before removing the tray, the copings are unscrewed to be removed along with the impression. The implant analogs are connected to the copings to fabricate the definitive cast (Lee et al., 2008b).

Twenty in vitro and one clinical study compared the accuracy with open-tray (direct, pickup) vs closed-tray (indirect, transfer) impression techniques. Nine in vitro studies reported that the open-tray technique was more accurate than the closed-tray for completely edentulous patients (Al Quran et al., 2012, Assif et al., 1992, Barrett et al., 1993, Carr, 1991, Martinez-Rus et al., 2013, Mostafa et al., 2010, Naconecy et al., 2004, Phillips et al., 1994, Stimmelmayr et al., 2012). Ten in vitro studies reported no difference (Chang et al., 2012, Del'Acqua et al., 2008, Del'acqua et al., 2012, Fernandez et al., 2013, Herbst et al., 2000, Humphries et al., 1990, Mpikos et al., 2012, Rashidan et al., 2012, Spector et al., 1990, Wenz and Hertrampf, 2008) and one in vitro study reported that the closed-tray was more accurate (Burawi et al., 1997). One clinical study reported that the open-tray was more accurate (Stimmelmayr et al., 2013).

In situations where four or more implants are used, a greater number of studies showed more accurate impressions with the open-tray technique (Papaspyridakos et al., 2014).

1.2. Splinting vs. Nonsplinting

Splinting of impression copings using a rigid material has been advocated as a technique to prevent individual coping movement and to take advantage of the stabilization of the impression copings during the impression making and analog attachment procedures (Akalin et al., 2013, Lee et al., 2008b).

Most of the studies used polymethyl methacrylate (PMMA) autopolymerizing acrylic resin as the splinting material of choice and different techniques have been tested, such as dental floss, prefabricated acrylic resin bars and stainless steel burs (Naconecy et al., 2004, Papaspyridakos et al., 2012). Nevertheless, distortion can result from the residual polymerization contraction of the resin used for splinting. The use of new splinting materials such as composite resin or visible light polymerizing acrylic resin showed better results (Stimmelmayr et al., 2013, Papaspyridakos et al., 2012, Del'Acqua et al., 2010b).

Twenty-two in vitro and three clinical studies compared the accuracy of splinted vs nonsplinted impression techniques. Twelve in vitro studies reported that the splinted technique was more accurate than the nonsplinted technique (Al Quran et al., 2012, Assif et al., 1992, Assif et al., 1996, Avila et al., 2012, Del'Acqua et al., 2010b, Hariharan et al., 2010, Martinez-Rus et al., 2013, Naconecy et al., 2004, Ongul et al., 2012, Stimmelmayr et al., 2012, Vigolo et al., 2004, Vigolo et al., 2003), nine in vitro studies reported that there was no difference (Barrett et al., 1993, Chang et al., 2012, Del'Acqua et al., 2008, Herbst et al., 2000, Hsu et al., 1993, Humphries et al., 1990, Kim et al., 2006, Mostafa et al., 2010, Spector et al., 1990) and one in vitro study (Phillips et al., 1994) reported that the nonsplinted technique was more accurate. The three clinical studies demonstrated that the splinted technique was more accurate than the nonsplinted technique and recommended this technique for clinical use (Papaspyridakos et al., 2012, Papaspyridakos et al., 2011, Stimmelmayr et al., 2013).

The splinted impression technique was more accurate than the nonsplinted conventional impression technique for completely edentulous patients (Papaspyridakos et al., 2014). Nevertheless, authors have identified potential problems with the spinted technique, such as fracture of the connection between the splint material and the impression copings, in particular due to shrinkage of splint material (Moreira et al., 2015).

1.3. Impression material

The properties of an impression material, including rigidity and dimensional stability, can influence the accuracy of the implant impression, the accuracy of the solid implant cast, and ultimately, the accuracy of the cast implant framework. When using the direct implant impression technique, the impression material must fulfill two requirements: 1) rigidity to hold the direct impression coping and to prevent accidental displacement of the coping when an abutment is connected, and 2) minimal positional distortion between abutment replicas as compared with their intraoral implant abutments (Wee, 2000).

A rigid elastomeric impression material, such as polyether (PE), would secure the impression copings accurately, and it has dimensional stability, high resistance to permanent deformation, and high primary shear resistance with little creep under compressive forces, making it an optimal material for making impressions of implants. Polyvynil siloxane (PVS) impression materials have been widely accepted because of their excellent dimensional stability, superior recovery from deformation, and precise reproduction of details (Del'Acqua et al., 2010a).

In recent years, superior chemical and physical properties have made PE and PVS the materials of choice for implant impression. To date, many researchers have evaluated implant impression accuracy and found better results with PE and PVS versus condensation silicone, polysulfide, irreversible hydrocolloid, and plaster materials (Akalin et al., 2013, Lee et al., 2008b).

Among the analyzed papers, the majority of the studies reported no difference between PE and PVS (Aguilar et al., 2010, Akalin et al., 2013, Assif et al., 1999, Barrett et al., 1993, Chang et al., 2012, Ferreira et al., 2012, Mostafa et al., 2010, Ortorp et al., 2005, Spector et al., 1990, Wee, 2000, Wenz and Hertrampf, 2008) while one study reported better accuracy with PE (Del'Acqua et al., 2010a).

A systematic review concluded that the accuracy of implant impressions is not affected by the impression material (PE and PVS) for completely edentulous patients (Papaspyridakos et al., 2014).

1.4. Impression type (Conventional vs. Digital)

The reproduction of dental implants in the oral cavity avoiding conventional impressions overcomes some problems of the indirect method. Digital impression scanners eliminate tray selection, dispensing and setting of impression materials, disinfection, and impression shipping to the laboratory, while increased patient comfort may be an additional advantage (Papaspyridakos et al., 2014). Limitations pertain to the additional cost of purchasing an intraoral scanner and the learning curve for adjusting to the new treatment modality (Papaspyridakos et al., 2015).

Research on digital implant impressions for completely edentulous jaws is limited to a few in vitro studies (Abdel-Azim et al., 2014, Papaspyridakos et al., 2015). Papaspyridakos et al., 2015 concluded that digital implant impressions are as accurate as conventional implant impressions. Abdel-Azim et al., 2014 reported that, for complete-arch frameworks, the digital impression resulted in an overall more accurate fit when compared to the conventional closed-tray impression.

1.5. Implant angulation and number

Some authors reported that when multiple implants are placed with different angulations, the distortion of the impression material on removal increases. Also, this effect may be heightened by an increasing number of implants (Assuncao et al., 2004, Carr, 1991, Sorrentino et al., 2010).

Conrad, et al. 2007 reported that the acceptable angulation of the implant that will not have an adverse effect on the impression accuracy was around 15º. They also demonstrated that accuracy has as well been shown to be inversely affected by number and angulation of the implants.

To clarify the relation between the angulation effect and the numbers of the implant, more studies are required (Lee et al., 2008b).

1.6. Other factors (Connection level – implant level/abutment level; Impression tray type – stock/custom tray; Depth of implant placement)

Other studies examined the effects of various factors on the accuracy of implant impressions, such as different connection levels (implant level and abutment level) (Alikhasi et al., 2011, Bartlett et al., 2002, Daoudi et al., 2001), different impression trays (Burns et al., 2003, Simeone et al., 2011) and implant depth (Lee et al., 2008a).

Too few studies were available to draw any conclusions. Further studies, including clinical trials, are required to provide more evidence about clinical factors that affect the implant impression accuracy.

1.7. Implant connection type (Internal vs. External)

One of the features that has been the object of debate among the systems is the design of the connection that allows the prosthetic suprastructure to be attached to the implants. Two types of connections are available: external and internal connection. While the external connection (EC) usually has an external hexagon on the implant platform, the internal connection (IC) can be divided into internal hexagon, internal octagon and Morse taper connection (Goiato et al., 2015).

Historically, the Bränemark system was characterized by an external hexagon which was developed to facilitate implant insertion and provide an antirotational mechanism. However, this configuration has some drawbacks due to the existence of a microgap in the implant-abutment interface and to its limited height. For this reason, it has been hypothesized that, under high occlusal loads, the external hexagon might allow micromovements of the abutment, consequently causing instability of the implant/abutment connection, which may result in abutment screw loosening or even fracture. IC implants were therefore introduced to increase the implant-abutment contact area, providing greater stability and bacterial seal (Goiato et al., 2015, Gracis et al., 2012).

To date, there is no *in vivo* or *in vitro* study that has directly compared the influence of internal and external implant connections for abutments/reconstructions on the accuracy of implant-level impressions. All in vitro studies reported separately on the two connection designs and they used different protocols. Therefore, the data could not be compared and no clinical recommendation can be made (Gracis et al., 2012, Papaspyridakos et al., 2014).

For this reason, the purpose of the present study is to evaluate if there is any significant difference in accuracy between implant-level impressions made on IC and EC implant systems. The following null hypothesis was tested in this study: (1) There were no differences in implant-level impressions accuracy between IC and EC implants.

II. Materials and Methods

1. Type of study

In vitro study.

2. Study design

This study compared the influence of two different types of implant connection on impression accuracy: **Group A** (internal connection - IC) and **Group B** (external connection - EC)**.** For each group, 10 sample impressions were made from a standardized master cast. After pouring, measurements were made in each working cast and the differences between them were analyzed.

3. Reference bars construction

3.1. Internal connection

A dental stone cast was fabricated by duplicating an edentulous mandibular arch. Four slightly oversized holes were made bilaterally in the intra-mental foramen region to insert four internal connection implant analogs (Biomet 3i®, Florida, USA) with 4,10mm diameter. The implant analogs were placed simulating a supra osseous clinical environment, parallel to each other and fixed using wax to make their removal possible after fabrication of the framework (**Figure 1**).

Figure 1. Initial cast – IC.

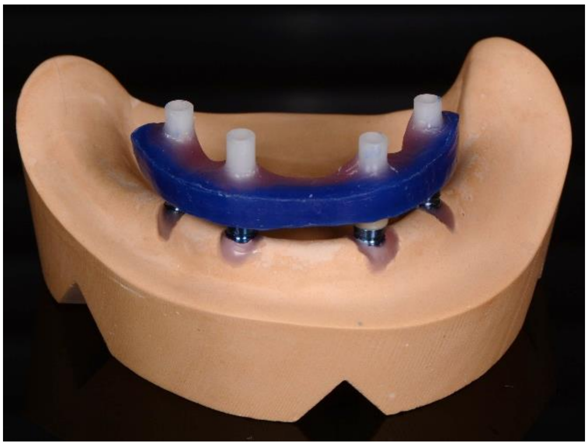


Figure 2. Reference bar wax-up – IC.

Corresponding burnout cylinders were placed on the implant analogs and splinted with wax (**Figure 2**) in order to fabricate a cobalt-chromium alloy framework (**Figures 3 and 4**).

Figure 3. Reference bar after casting- IC.

Figure 4. Reference bar finished – IC.

3.2. External connection

To ensure the same position of implant analogs on both groups, a transference bar was fabricated using IC 1mm-multi-units and respective multi-unit impression copings (Biomet 3i®, Florida, USA) (**Figure 5**).

Figure 5. 1mm-multiunits and impression copings in place.

Figure 6. Transference bar with IC components.

The copings were splinted using PMMA autopolymerizing acrylic resin (GC pattern™; GC Corp, Tokyo, Japan) (**Figure 6**).

Then, the complex was removed from the cast and the IC multi-units and implant analogs were substituted by EC components (**Figure 7**).

The EC analogs were incorporated into the stone cast attached to the transference bar (**Figure 8**).

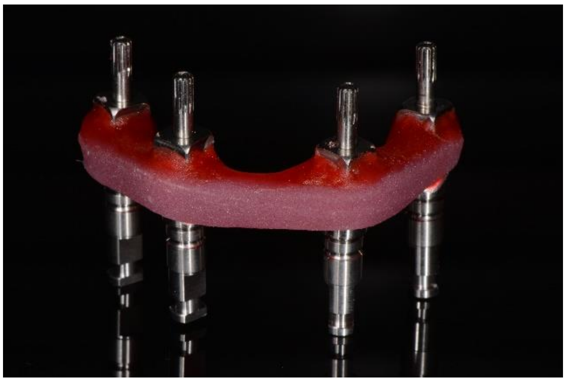


Figure 7. Transference bar with EC components.

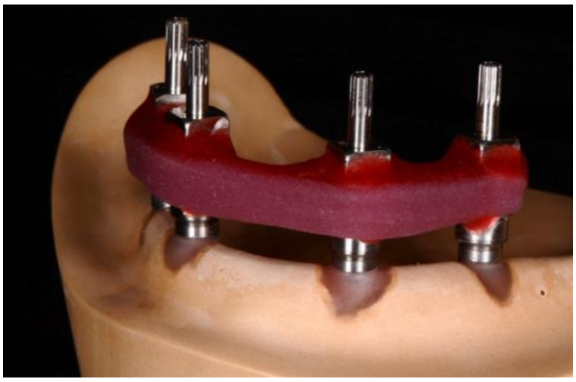


Figure 8. Positioning of EC implant analogs.

Next, a framework for EC group was fabricated, using the same protocol used for the IC reference bar (**Figures 9 and 10**).

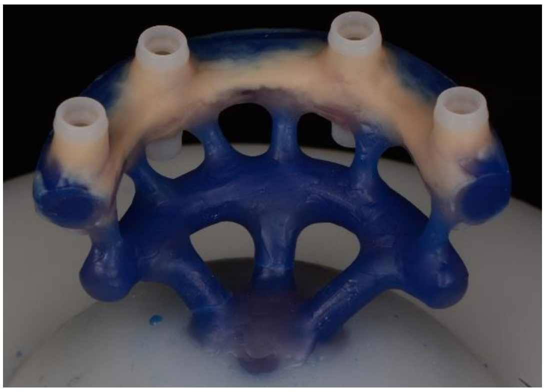


Figure 9. Reference bar wax-up – EC.

Figure 10. Reference bar finished – EC.

The reference bars were used as a standard to evaluate the accuracy of casts produced from impressions.

4. Master casts construction

For both groups, implant analogs were attached to the respective reference frameworks and then inserted into the holes on the stone cast, in order to guarantee a complete passive fit. A matrix for pouring the definitive master casts was made using condensation silicone (Zetalabor; Zhermack®, Badia Polesina, Italy) over the stone cast with the respective reference bar attached.

Two master models (EC and IC) were fabricated with polyurethane (Sherapolan 2:1; Shera®, Lemförde, Germany) (**Figures 11 and 12**).

Figure 11. Master cast – EC after removing the silicone matrix.

Figure 12. Master cast – IC.

The four implant analogs were numbered anti-clockwise from 1 to 4 based on a frontal view of the master cast.

5. Impression procedure

Acrylic stock trays were used for all impressions in the unsplinted open-tray technique. Four openings were drilled to allow access for the coping screws and a thin layer of polyether adhesive (Impregum™; 3M ESPE, Seefeld, Germany) was applied to improve adhesion (**Figure 13**).

Figure 13. Polyether adhesive application.

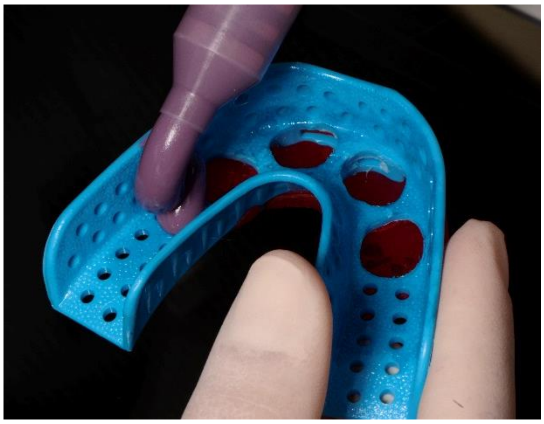


Figure 14. Polyether insertion.

Twenty medium - consistency polyether (Impregum™ Penta™; 3M ESPE, Seefeld, Germany) impressions were made - ten for each model/group - in accordance with manufacturer's directions. The impression material was mixed with an automatic mixing device (Pentamix™ II; 3M ESPE, Seefeld, Germany) (**Figure 14**) and part of the material was meticulously injected with a syringe (Penta Elastomer syringe; 3M ESPE, Seefeld, Germany) around the impression copings to ensure complete coverage of the copings (**Figure 15**). The tray was seated on master cast with hand pressure throughout the setting time - 6 minutes (**Figure 16**).

Figure 15. Polyether injection around copings.

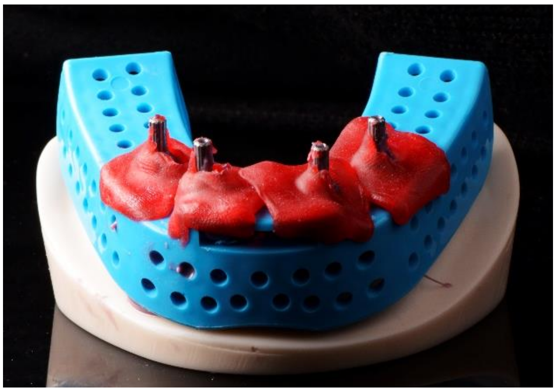


Figure 16. Impression procedure – open tray technique.

The guide pins were unscrewed so that the transfer copings remained in the impression when the tray was removed.

For all impressions, implant transfer copings (Biomet 3i®, Florida, USA) for the open tray technique were used.

6. Cast production protocol

Standardized laboratory procedures were performed after at least 30 minutes. First, matching implant analogs were attached manually to the transfer copings.

Then, the impressions were poured with type IV dental stone (GC Fujirock EP®; GC Corp, Tokyo, Japan) and vacuum-mixed following manufacturer recommendations (**Figures 17 and 18**). A single operator performed all laboratory procedures. All casts were stored at room temperature for a minimum of 24 hours before measurements were made.

Figure 17. EC cast – upper view.

Figure 18. EC cast – front view.

7. Measurement protocol

Each cast produced was assessed for accuracy by attaching the respective reference framework with a single screw on analog number 1 (**Figure 19**) and measuring the vertical fit discrepancy using a toolmakers' microscope (Toolmakers Microscope, Mitutoyo) (**Figure 20**).

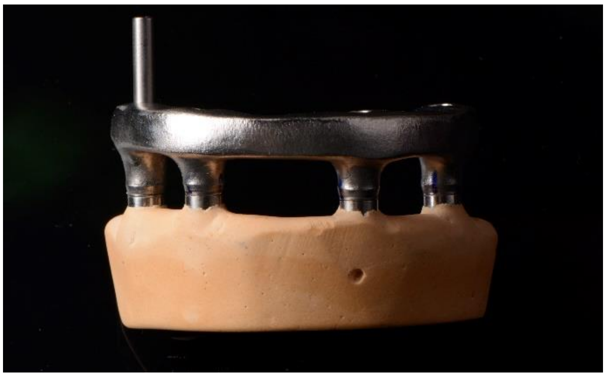


Figure 19. Reference bar with a single screw on analog number 1.

Figure 20. Toolmakers' microscope.

The accuracy of bar fit was quantified by measuring the vertical gap between each cylinder and the respective analog (2, 3 or 4) at four different points - buccal, lingual, distal and mesial. Demarcations were made in the center of each side of the framework's cylinders to standardize the area for image capture. All measurements were done by the same operator.

8. Statistical analysis

The statistical analysis of the results was performed at three levels:

1) In Group A, a comparison of all buccal, lingual, mesial and distal measures was made separately;

2) In Group B, a comparison of all buccal, lingual, mesial and distal measures was made separately;

3) A comparison between Group A and B was performed by evaluating each implant (2, 3 or 4) / point (buccal, lingual, distal or mesial) combination.

Kolmogorov-Smirnov and **Shapiro-Wilk Tests** were used to access whether the data followed a normal distribution; the **Levene's Test** was computed to determine if the assumption of equal variances was valid.

Kruskall-Wallis and **Mann-Whitney Tests** (Nonparametric Tests) were performed accordingly to the size of the sample, when the conditions referred were not observed (normal distribution and equal variances).

T-student Test (Parametric Test) was performed when the conditions referred were observed (normal distribution and equal variances).

The level for statistical significance was set at 5% (0,05) for all tests that were performed.

III. Results

The results of the study in terms of measurements obtained through the microscope analysis are summarized in **Appendix D.** In each model, the vertical gap was measured on implant analog number 2, 3 and 4; for each implant analog the measurements were made at four different points – buccal, lingual, distal and mesial.

1. Group A – Internal Connection

In Group A, in order to compare all buccal, lingual, mesial and distal values separately between implant analogs, a nonparametric test was applied due to the small size of the samples, and because after performing **Shapiro-Wilk Test** it was verified for all categories that the measurements on the 3 samples (implant analog 2, 3 and 4) did not follow a normal distribution.

Since the intention is to compare more than 2 samples, the nonparametric test **Kruskall-Wallis** was performed. The results show there are no significant differences between implant analogs concerning distances at buccal, lingual, mesial and distal points, since the p-value>0,05 (**Table 1**).

Table 1

Statistical Comparison of Each Point between Implant Analogs – Group A

	Data follow normal distribution	**Significant differences between implant analogs**
Buccal points	**No** (2p-values<0,05)	**No** (p-value>0,05)
Lingual points	**No** (1p-value<0,05)	**No** (p-value>0,05)
Mesial points	**No** (2p-values<0,05)	**No** (p-value>0,05)
Distal points	**No** (1p-value<0,05)	**No** (p-value>0,05)

2. Group B – External Connection

In Group B, in order to compare all buccal, lingual, mesial and distal values separately between implant analogs, a nonparametric test was applied due to the small size of the samples, and because after performing **Shapiro-Wilk Test** it was verified that all but one (buccal points) did not follow a normal distribution. However, **Levene's Test** determined that the assumption of equal variances was not valid for this category.

Since the intention is to compare more than 2 samples, the nonparametric test **Kruskall-Wallis** was performed. The results show there are significant differences between implant analogs concerning distances at buccal and mesial points, since the p-value<0,05 (**Table 2**).

Table 2

Statistical Comparison of Each Point between Implant Analogs – Group B

	Data follow normal distribution	**Significant differences between implant analogs**
Buccal points	**Yes** (values>0,05)	**Yes** (p-value<0,05)
Lingual points	**No** (1p-value<0,05)	**No** (p-value>0,05)
Mesial points	**No** (1p-value<0,05)	**Yes** (p-value<0,05)
Distal points	**No** (1p-value<0,05)	**No** (p-value>0,05)

With respect to buccal and mesial points, statistically significant differences were observed between implant analogs 2 and 3 and between implant analogs 2 and 4. It was verified that the vertical gap on implant analog 2 is significantly lower than the ones on implant analogs 3 and 4.

3. Comparison between Groups

The comparison between Group A and B was performed by analysing each implant analog/point combination.

After performing **Shapiro-Wilk Test**, it was verified that the measurements at each combination did not all follow normal distribution.

When data followed normal distribution, **T-student Test** (parametric test) was performed. On the other hand, **Mann-Whitney Tests** (nonparametric tests) was used if the values did not come from normal populations.

The results show <u>there are significant differences</u> between internal and external connections, concerning measurements in all implant/point combinations (**Table 3**).

Larger gaps were found when the measurements in the stone casts were obtained from external connection group.

It was concluded that Group B (external connection) presented vertical gaps statistically higher than the ones verified in Group A (internal connection).

Table 3

Statistical Comparison of Each Combination between Group A and B

	Data follow normal distribution	**Significant differences between implant analogs**
Implant 2, Buccal point	**No** (1p-values<0,05)	**Yes** (p-value<0,05)
Implant 2, Lingual point	**Yes** (p-values>0,05)	**Yes** (p-value<0,05)
Implant 2, Mesial point	**No** (p-values<0,05)	**Yes** (p-value<0,05)
Implant 2, Distal point	**Yes** (p-values>0,05)	**Yes** (p-value<0,05)
Implant 3, Buccal point	**Yes** (p-values>0,05)	**Yes** (p-value<0,05)
Implant 3, Lingual point	**No** (1p-values<0,05)	**Yes** (p-value<0,05)

(to be continued)

(continuation)

Implant 3, Mesial point	**Yes** (p-values>0,05)	**Yes** (p-value<0,05)
Implant 3, Distal point	**Yes** (p-values>0,05)	**Yes** (p-value<0,05)
Implant 4, Buccal point	**No** (1p-values<0,05)	**Yes** (p-value<0,05)
Implant 4, Lingual point	**No** (p-values<0,05)	**Yes** (p-value<0,05)
Implant 4, Mesial point	**No** (1p-values<0,05)	**Yes** (p-value<0,05)
Implant 4, Distal point	**No** (p-values<0,05)	**Yes** (p-value<0,05)

Table 4

Descriptive Statistics of the Vertical Gap in mm for the Two Groups Tested - Buccal

	N	**Mean**	**Min**	**Max**
Internal Connection	30	0,020	0,007	0,061
External connection	30	0,058	0,012	0,155

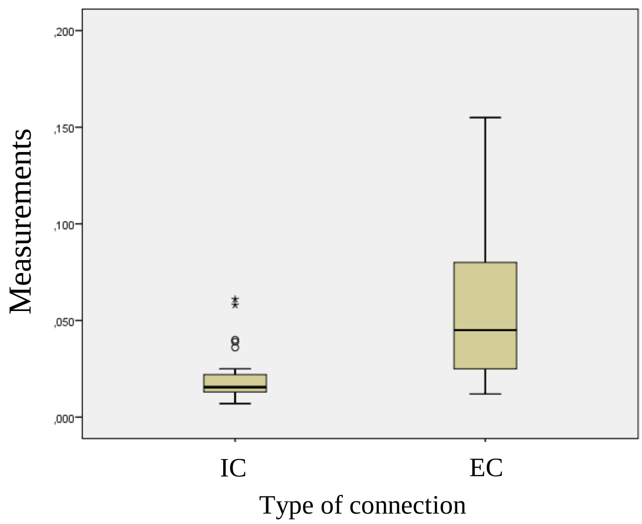


Figure 21. Box-whisker plots of the vertical gap in mm for the two groups tested – buccal points

Table 5

Descriptive Statistics of the Vertical Gap in mm for the Two Groups Tested - Lingual

	N	Mean	Min	Max
Internal Connection	30	0,017	0,005	0,074
External connection	30	0,056	0,012	0,156

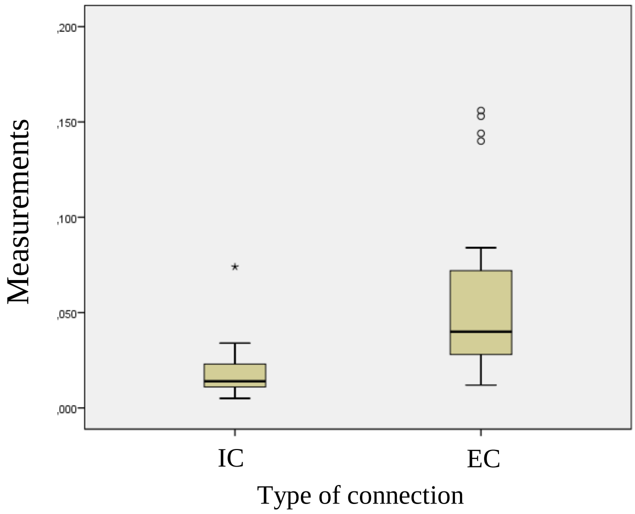


Figure 22. Box-whisker plots of the vertical gap in mm for the two groups tested – lingual points

Table 6

Descriptive Statistics of the Vertical Gap in mm for the Two Groups Tested - Mesial

	N	Mean	Min	Max
Internal Connection	30	0,017	0,006	0,066
External connection	30	0,053	0,011	0,133

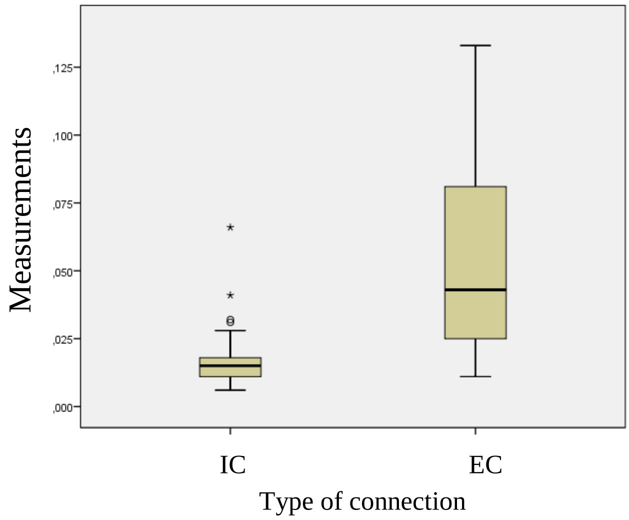


Figure 23. Box-whisker plots of the vertical gap in mm for the two groups tested – mesial points

Table 7

Descriptive Statistics of the Vertical Gap in mm for the Two Groups Tested - Distal

	N	Mean	Min	Max
Internal Connection	30	0,019	0,007	0,095
External connection	30	0,053	0,015	0,176

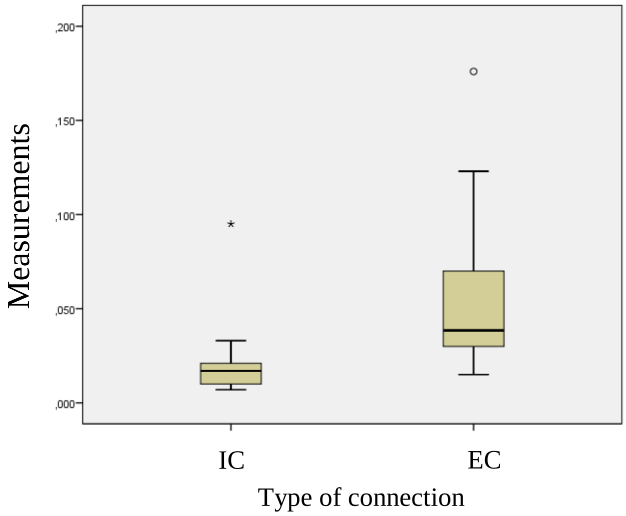


Figure 24. Box-whisker plots of the vertical gap in mm for the two groups tested – distal points

IV. Discussion

The results suggest that internal connection implants (Group A) yielded significantly more accurate impressions than external connection implants (Group B).

The null hypothesis that there would be no significant differences on the accuracy of implant impressions produced by tested implant connection types was rejected. Since there are no previously published *in vivo* or *in vitro* studies evaluating the influence of the same factor (implant connection type), the conclusion of this investigation cannot be compared.

Working casts should accurately represent the clinical relationship of the implants allowing the fabrication of passively-fitting prostheses. Consequently, there will be an elimination of strain on the supporting implant components and the surrounding bone (Del'Acqua et al., 2008). The effect of different factors on the accuracy of implant impressions has been mainly investigated *in vitro* resulting in limited clinical data.

Although most authors emphasize that a "passive fit" of a multi-implant framework cannot be achieved, the amount of misfit and resultant stress that can be clinically accepted is still unknown (Wenz and Hertrampf, 2008).

The different connection geometry between and within commercially available implant systems may affect the accuracy of impressions. Several studies have evaluated the accuracy of impression techniques with external connection implants, but only few studies have examined the same factor in internal connection implants. The different results among studies of EC and IC implants are the consequence of employing different prosthetic connection mechanisms and measurements methods (Mpikos et al., 2012).

There are large differences in the mean values and standard deviations in this study. In most measurements, the connections showed good mean results, but with great variations. This fact implies that the same connection does not behave homogenously. The results can be influenced by the micrometric tolerance inherent in the machining of the prosthodontic components and by the measurement method employed. Just one screw was tightened to the framework, leading to amplification of the gap values (Del'Acqua et al., 2008).

The results obtained are in conformity with the data from the reports by Jemt, 1991 and Tan et al., 1993. The authors suggested that the one-screw test for evaluation of framework fit showed that vertical discrepancies tend to be magnified at the opposite terminal abutment. The only exception is the mesial point in the external connection group which showed higher measurements on implant analog number 3 than on number 4. However, these discrepancies are often masked if the distortion occurred in the negative z-axis direction (Fernandez et al., 2013).

In 1994, Kalus and Bessing developed a rating scale for evaluation of the fit of a framework. In this study, the prosthesis was seated on abutments and tightened with one screw in the abutment number 1. The vertical gap between the cylinder and the abutment number 4 was given a rating using a 4-point scale: 0=no visible discrepancy, 1=slight discrepancy indicating a clear elevation of the framework with a gap less than 0,5mm, 2= a moderate discrepancy of approximately 0,5 to 1mm, and 3=pronounced discrepancy with a gap of clearly more than 1mm. If this classification had been used in the present study, all the results would have been 0 or 1, since the largest gap value measured for an analog was 0,176 mm (176 µm). In cases where the fit was 0, a gap between the abutment and framework would have been detectable only microscopically (Del'Acqua et al., 2008).

No specific range of acceptable misfit has yet been established (Ma et al., 1997). However, the significance of passive clinical fit of an implant-supported prosthesis has been highlighted in the literature to prevent complications (Papaspyridakos et al., 2011). Experienced operators cannot detect clinically discrepancies of less than 30µm in the fit of an implant-retained framework on multiple abutments. This figure could serve as a criterion between acceptable and unacceptable frameworks (Herbst et al., 2000). Jemt, 1991 and May et al,. 1997 suggested that discrepancies on the order of 100 to 150µm fall within a clinical range of passive fit. Thus, it appears that based on the findings of this study any of the connection types examined produce clinically acceptable results, if evidence-based protocols are followed. The lack of any reference value for defining misfit makes it difficult to recommend any particular type of connection.

The results of this study underline that even with standardized in vitro conditions the exact spatial reproduction of the implant positions in a working cast is not obtainable. Thus, the ideal objective is difficult to fully realize clinically because of the potential for distortion of the stone cast, which is caused by a combination of dimensional errors in the transfer process of the replicas, and also because framework adaptation may change when the retaining screws are tightened (Herbst et al., 2000).

It should also be noted that, unlike external-hexagon connections, the internal-connection configurations adopted by different implant manufacturers are not alike. With respect to the implant-abutment coupling of internal-connection implant systems, many differences have been described (Goiato et al., 2015). These differences might have a profound impact on clinical procedures and protocols. Some internal connection configurations have an intimate fit with the respective impression copings, which can make the impression more difficult to take and, therefore, may generate a higher degree of distortion (Gracis et al., 2012).

Implant components displacements can be introduced during the process of producing a definitive cast. The first is the displacement of each impression coping on the mating surface of each implant. The difference in rest position between the components when they are screwed is defined as machining tolerance.(Fernandez et al., 2013).

Manufacturing variables may contribute to the intimacy of the fit of implant and prosthetic components: machining tolerances of implant components, materials used in the manufacturing process, and the resultant physical and mechanical properties of the components (Martinez-Rus et al., 2013). Machining tolerance differs among different implant systems, representing an unknown variable in accuracy measurements (Ma et al., 1997). Herbst et al., 2000 showed that connecting an impression coping or an abutment replica could introduce more than 30 µm of displacement. Therefore, when the results of the studies investigating implant impression accuracy are interpreted, the machining tolerance should be considered as one of the factors affecting accuracy (Martinez-Rus et al., 2013)

The second factor is the displacement of each impression coping from the impression technique. Unscrewing the guide pins from the impression copings when the tray is removed from the mouth/model or screwing the matching abutment replicas in the impression may cause minor movement and thus influence cast accuracy (Vigolo et al., 2003).

Paired prosthetic components may be rotationally displaced during connection to their respective parts. This displacement cannot be controlled by the clinician and lies within the range of the inherent machining tolerance. Hence, errors occur during the connection of impression copings to the implants intraorally and to the implant analogs in the laboratory, respectively (Papaspyridakos et al., 2012).

A possible limitation of the present study is the use of manual torque to tighten the reference framework to the work casts. A torque driver should be used in order to apply an even force of 10Ncm.With a higher torque, there would have been a risk of screw fracture, the vertical discrepancy would have been reduced, and there inevitably would have been transfer of stresses to the implant analogs and screws (Del Acqua et al., 2010). Nevertheless, dentists in their clinical practice usually apply the method used in this study.

The methodology of the present study was standardized to allow a careful evaluation of different types of connection, while isolating other related variables, particularly those associated with laboratory procedures: setting time, use of direct technique, machine mixed impression material.

Some authors reported that implant angulation causes distortion of the impression material on removal. Thus, the greater the divergence between analogs, the more imprecise the impression will be (Del'Acqua et al., 2008). It should be noted that the implant analogs in the master casts of this study were parallel to each other and perpendicular to the surface, which minimized this factor.

None of the prosthesis fabrication methods employed have been able to produce frameworks with absolute passive fit (Papaspyridakos et al., 2011). A perfect fit occurs when all the matching surfaces of the implant and framework are in alignment and in contact without the application of force (Del Acqua et al., 2010). In this study, the lost-wax technique was used to fabricate the reference bar used throughout the measurements. It is known that the accuracy of this technique depends on multiple factors, including waxing technique and alloy behavior (Fernandez et al., 2013). In order to control these error sources, the position of the implant analogs in the master cast was determined only after casting the reference framework, attaching the analogs to the respective bar before pouring the definitive models.

The fact that implant analogs were placed in the same position in both groups using the transference bar, minimized the differences between them and standardized the conditions.

In several in vitro studies, master models that were block shape and had flat impression surfaces were included. However, neither of these can simulate the deformation that takes place in impression material upon removal, since curved-arch models were not used (Akalin et al., 2013). In the current study, two master models with an anatomic shape resembling the edentulous mandible were used.

Accordingly to the literature, the use of polyether or polyvinyl siloxane for direct multi-implant impressions for edentulous arches produces similarly accurate implant casts (Chang et al., 2012).

Splinting directly impression copings is often used as a technique to eliminate rotational movement and to take advantage of the stabilization of the impression copings. However, in this situation, can be seen as an error factor due to multiples variables: type of material, amount of material and its shrinkage. As an alternative, an impression material with adequate rigidity was used as recommended (Akalin et al., 2013). When used by itself, PE simplified the impression procedure, reduced the time required and minimized the chance of accidental displacement of the direct impression coping when the replicas were tightened (Del'Acqua et al., 2008).

In assessing the evidence to establish best practices, it is relevant that mixing techniques may account for the range of reported findings with respect to polyether performance. The application of the automix system has demonstrated greater control in polyether material manipulation when compared with manual mixing (Papaspyridakos et al., 2012).

The impressions were made in a controlled-temperature environment (23ºC± 2ºC) and no control of the humidity. The manufacturer's setting time was doubled in order to compensate for a delayed polymerization reaction at room temperature rather than at mouth temperature (Del Acqua et al., 2010).

Few articles have evaluated the influence of tray type on the accuracy of implant impressions. Burns et al. 2003 showed that custom trays produce more precise impressions than stock trays. Nevertheless, because of the additional time and cost required to fabricate custom trays, dentists tend to use stock trays that show favorable results, when correctly chosen. (Del'acqua et al., 2012).

The pouring procedure can alter the analogs' relationship because of the plaster expansion (Del'Acqua et al., 2010a). To minimize this factor, some techniques have been reported: The double-pouring technique minimizes the volumetric expansion of the stone and has been shown to lead to more accurate die casts. After connection of the implant analogs to the copings, an initial pour of vacuum-mixed die stone up to the middle of the analogs is carried out. After 30 minutes, the second pour of die stone is performed (Papaspyridakos et al., 2012); other option is the latex-tube pouring technique. Tubes are fitted onto the analogs, and pouring is performed by the conventional technique. After initial setting (approximately 10 minutes) the latex tubes are remove and a smaller quantity of dental stone is syringed around each analog (Del'Acqua et al., 2008).

Although none of these techniques have been used in this study, IV dental stone was employed because of its linear setting expansion of 0,10% at most (Fernandez et al., 2013, Herbst et al., 2000) and vacuum-mixed following manufacturer recommendations.

In this study, microscopy was used to measure the gap width between the metal framework and the analogs of the respective working cast at selected points. However, because inaccuracy is expressed in only one dimension, information may be lost (Martinez-Rus et al., 2013). The imprecisions seen in these vertical measurements may be enough to demonstrate the complexity of achieving “passive fit”. For further improvement, more research in this area should be performed to evaluate eventual tridimensional movements of implant analogs in the working casts.

Further studies are required to fully understand the influence of the connection type on the accuracy of implant impressions. To corroborate the findings of the present study, larger samples and another implant systems should be evaluated. Moreover, knowledge of the machining tolerances for the specific implant systems could be necessary before making fit measurements (Braian et al., 2014).

Although this investigation indicates that external connection implants produce significantly more inaccurate impressions comparing with internal connection type, additional *in vivo* studies would be helpful to establish the clinical relevance of this finding. Is also necessary to define the threshold that distinguishes misfit from acceptable fit (Braian et al., 2014). This information could be useful for clinicians to understand and respect the level of precision that is needed for implant-supported prostheses on the implant level.

V. Conclusion

Within the limitations of the present laboratory study, the results suggest that internal connection implants present better results on the accuracy of implant impressions comparing to external connection implants. Implant-level impressions made on external connection implants resulted in statistically lower accuracy than the internal connection group.

Clinical significance: Improved accuracy of implant impressions may be obtained if internal connection implants are used.

VI. Appendices

APPENDIX A

Implant components, References and Batch Numbers

Table 8

Materials, Manufacturers, Components and Batch Numbers

Manufacturer: Biomet 3i®, Florida, USA **Description**	**Reference**	**Batch number**
Internal connection Implant Analog (master cast)	IILA 20 4.1mm	1176262
Internal connection Implant Analog (master cast)	IILA 20 4.1mm	1176262
Internal connection Implant Analog (master cast)	IILA 20 4.1mm	1176262
Internal connection Implant Analog (master cast)	IILA 20 4.1mm	1176413
External connection Implant Analog (master cast)	ILA 20 4.1mm	1174319
External connection Implant Analog (master cast)	ILA 20 4.1mm	1177288
External connection Implant Analog (master cast)	ILA 20 4.1mm	1177288
External connection Implant Analog (master cast)	ILA 20 4.1mm	1174098
Internal connection Multiunit (transference bar)	ILPC441U 1mm	2014080573
Internal connection Multiunit (transference bar)	ILPC441U 1mm	2014101610
Internal connection Multiunit (transference bar)	ILPC441U 1mm	2014101610
Internal connection Multiunit (transference bar)	ILPC441U 1mm	2014101610
External connection Multiunit (transference bar)	LPC441U 1mm	2012110288
External connection Multiunit (transference bar)	LPC441U 1mm	2013101326
External connection Multiunit (transference bar)	LPC441U 1mm	2013092050
External connection Multiunit (transference bar)	LPC441U 1mm	2014090941
Multiunit impression coping (transference bar)	LPCPIC2	2014102238
Multiunit impression coping (transference bar)	LPCPIC2	2014102238
Multiunit impression coping (transference bar)	LPCPIC2	2014102238
Multiunit impression coping (transference bar)	LPCPIC2	2014102238
Internal connection impression coping (impressions)	IIIC41	1179859
Internal connection impression coping (impressions)	IIIC41	1179351
Internal connection impression coping (impressions)	IIIC41	1178604
Internal connection impression coping (impressions)	IIIC41	1179351
External connection impression coping (impressions)	IIC12	1162761
External connection impression coping (impressions)	IIC12	1162761
External connection impression coping (impressions)	IIC12	1118757
External connection impression coping (impressions)	IIC12	1162761

(to be continued)

(continuation)

Description	**Reference**	**Batch number**
Internal connection Implant Analog (study cast)	IILA20	1170466
Internal connection Implant Analog (study cast)	IILA20	1170466
Internal connection Implant Analog (study cast)	IILA20	1170466
Internal connection Implant Analog (study cast)	IILA20	1170466
Internal connection Implant Analog (study cast)	IILA20	1175319
Internal connection Implant Analog (study cast)	IILA20	1175319
Internal connection Implant Analog (study cast)	IILA20	1175319
Internal connection Implant Analog (study cast)	IILA20	1175319
Internal connection Implant Analog (study cast)	IILA20	1175319
Internal connection Implant Analog (study cast)	IILA20	1175319
Internal connection Implant Analog (study cast)	IILA20	1175319
Internal connection Implant Analog (study cast)	IILA20	1175319
Internal connection Implant Analog (study cast)	IILA20	1175319
Internal connection Implant Analog (study cast)	IILA20	1175319
Internal connection Implant Analog (study cast)	IILA20	1175319
Internal connection Implant Analog (study cast)	IILA20	1175319
Internal connection Implant Analog (study cast)	IILA20	1175319
Internal connection Implant Analog (study cast)	IILA20	1180124
Internal connection Implant Analog (study cast)	IILA20	1175319
Internal connection Implant Analog (study cast)	IILA20	1175319
External connection Implant Analog (study cast)	ILA20	1180076
External connection Implant Analog (study cast)	ILA20	1177296
External connection Implant Analog (study cast)	ILA20	1177288
External connection Implant Analog (study cast)	ILA20	1177288
External connection Implant Analog (study cast)	ILA20	1180323
External connection Implant Analog (study cast)	ILA20	1180323
External connection Implant Analog (study cast)	ILA20	1180323
External connection Implant Analog (study cast)	ILA20	1180323
External connection Implant Analog (study cast)	ILA20	1180323
External connection Implant Analog (study cast)	ILA20	1180323
External connection Implant Analog (study cast)	ILA20	1180076
External connection Implant Analog (study cast)	ILA20	1180076
External connection Implant Analog (study cast)	ILA20	1178095
External connection Implant Analog (study cast)	ILA20	1178095
External connection Implant Analog (study cast)	ILA20	1178095
External connection Implant Analog (study cast)	ILA20	1178095
External connection Implant Analog (study cast)	ILA20	1178095
External connection Implant Analog (study cast)	ILA20	1178095
External connection Implant Analog (study cast)	ILA20	1178095
External connection Implant Analog (study cast)	ILA20	1178095

APPENDIX B

Impregum™ Penta™ – Instructions for use

Table 9

Impregum™ Penta™ use According to the Manufacturer's Instructions

Manufacturer: 3M ESPE, Seefeld, Germany

Prepare impression trays

For sufficient adhesion, apply a thin layer of Polyether Adhesive to the tray and allow to dry completely (at least 30-60 sec – 15min drying time are optimal)

Prepare Pentamix™/ Penta Cartridge

With newly filled cartridges, start mixing and extrude and discard the first unevenly mixed paste prior to the first use for impression taking. Do not use the paste to take an impression until the color of the paste is homogeneous.

Dosing and Mixing

Dosing and mixing are performed automatically in the Pentamix™.

Times

	Working Time from start of mixing* min:sec	Setting Time from start of mixing* min:sec	Intraoral Setting Time min:sec
Symbols on product		—	
Impregum Penta	02:45	06:00	03:15

Model preparation

Prepare a cast from the impression with a sprecialized stone plaster no earlier than 30 min and no later than 14 days after impression taking

Notes

● At temperatures below 18º, the viscosity of the pastes may increase sufficiently to make mixing in the device difficult. After keeping the pastes at 18ºC for at least one day, the processability is re-established without compromising quality.

● Store the product at 18-25ºC.

● Direct exposure to sunlight and damp storage conditions may damage the impression

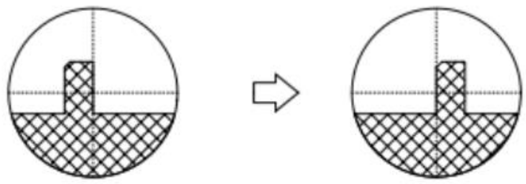
APPENDIX C

Mitutoyo Toolmaker’s Microscope – Instructions for measurement

3.2 Measurement

3.2.1 Dimensional measurement

Align a measuring point on the workpiece with one of the cross-hairs and take the reading from the Micrometer Head. Then, move the XY stage by turning the Micrometer Head and align another measuring point with the same cross-hair and take the reading at this point. The difference between the two readings represents the dimension between the two measuring points.



A Digimatic Head and Digital Counter can be used, in place of the Micrometer Head, for digital display of the displacement. They also eliminate reading errors. Since the zero-set button zeroes the counter at any position, the displacement can be read directly.

Figure 25. Measurement procedure according to user’s manual - Mitutoyo Toolmaker’s Microscope.

APPENDIX D

Measurements obtained on Microscope Analysis

Table 10

Measurements of the Vertical Gaps in mm – Group A (Internal Connection)

	Implant Analog 2				Implant Analog 3				Implant Analog 4			
	B	**L**	**M**	**D**	**B**	**L**	**M**	**D**	**B**	**L**	**M**	**D**
I1	0,040	0,024	0,041	0,022	0,036	0,023	0,015	0,021	0,058	0,034	0,028	0,033
I2	0,022	0,014	0,013	0,026	0,039	0,024	0,031	0,028	0,061	0,074	0,066	0,095
I3	0,018	0,021	0,020	0,009	0,022	0,028	0,032	0,020	0,025	0,024	0,022	0,031
I4	0,012	0,018	0,007	0,012	0,019	0,019	0,017	0,014	0,015	0,023	0,017	0,017
I5	0,013	0,008	0,012	0,007	0,007	0,005	0,012	0,015	0,014	0,015	0,015	0,017
I6	0,010	0,007	0,011	0,009	0,015	0,007	0,007	0,013	0,022	0,012	0,006	0,018
I7	0,011	0,012	0,013	0,009	0,019	0,010	0,011	0,020	0,013	0,013	0,015	0,007
I8	0,015	0,017	0,015	0,022	0,020	0,012	0,018	0,020	0,013	0,016	0,011	0,010
I9	0,016	0,014	0,016	0,017	0,018	0,006	0,015	0,017	0,012	0,011	0,009	0,009
I10	0,009	0,013	0,014	0,012	0,009	0,012	0,015	0,014	0,014	0,008	0,007	0,009

Table 11

Measurements of the Vertical Gaps in mm – Group B (External Connection)

	Implant Analog 2				Implant Analog 3				Implant Analog 4			
	B	**L**	**M**	**D**	**B**	**L**	**M**	**D**	**B**	**L**	**M**	**D**
E1	0,043	0,078	0,063	0,074	0,155	0,156	0,122	0,101	0,108	0,057	0,060	0,036
E2	0,040	0,033	0,025	0,033	0,108	0,144	0,116	0,105	0,089	0,153	0,130	0,176
E3	0,034	0,052	0,024	0,059	0,129	0,084	0,133	0,123	0,058	0,034	0,033	0,040
E4	0,034	0,043	0,045	0,037	0,051	0,050	0,046	0,050	0,037	0,026	0,022	0,031
E5	0,027	0,035	0,024	0,037	0,080	0,053	0,081	0,070	0,129	0,140	0,087	0,115
E6	0,023	0,028	0,017	0,027	0,078	0,067	0,087	0,051	0,071	0,082	0,083	0,085
E7	0,021	0,026	0,027	0,024	0,025	0,036	0,028	0,022	0,028	0,033	0,028	0,025
E8	0,017	0,016	0,028	0,015	0,069	0,025	0,065	0,032	0,047	0,037	0,047	0,042
E9	0,018	0,035	0,018	0,024	0,022	0,028	0,018	0,034	0,063	0,072	0,057	0,051
E10	0,012	0,012	0,011	0,015	0,023	0,021	0,032	0,030	0,112	0,048	0,041	0,047

VII. References

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